CLAIMS

What is claimed is:

1. A method for removing contaminants from a surface of an object to be cleaned, the method comprising:

providing a cleaning device fluidically connected to a high-pressure gas supply, the device comprising at least one high-pressure passage of a predetermined miniature lateral scale with a high-pressure outlet for accelerating the gas, the high-pressure outlet characterized by at least one narrow lip, the outlet and the narrow lip defining an active surface;

bringing the active surface of the cleaning device to a predetermined miniature gap from, and substantially parallel to, the surface of the object to be cleaned, thus defining a throat section associated with the device between said at least one narrow lip and the surface of the object to be cleaned, wherein the gap is the width of the throat section;

accelerating the gas to about sonic speeds at the throat section;

thereby producing lateral aeromechanic removal forces that act on the contaminants.

2. The method of claim 1, wherein the width of the throat section is reduced below a predetermined distance to attain a high gradient of velocity of the gas, thereby controlling mass flow.

3. The method of claim 1, wherein the width of the throat section is regulated.

4. The method of claim 1, wherein the width of the throat section is in the order of 100 to 1000 microns.

5. The method of claim 1, wherein the width of the throat section is about 30 to 100 microns.

6. The method of claim 1, wherein the width of the throat section is about 30 microns or less.

7. The method of claim 1, wherein the narrow lip is sharp.

8. The method of claim 1, wherein the lateral scale of the high-pressure passage is about the same in size as the width of the throat section.

9. The method of claim 1, wherein the lateral scale of the high-pressure passage is significantly larger than the width of the throat section.

10. The method of claim 1, wherein the lateral scale of the high-pressure passage is significantly smaller than the width of the throat section.

11. The method of claim 1, wherein pressure of the high-pressure gas supply is regulated.

12. The method of claim 1, wherein pressure of the high-pressure gas supply is up to 5 bars.

13. The method of claim 1, wherein pressure of the high-pressure gas supply is up to 20 bars.

14. The method of claim 1, wherein pressure of the high-pressure gas supply is up to 100 bars.

15. The method of claim 1, further comprising evacuating the gas through at least one gas evacuation passage, confining said at least one high-pressure outlet within, and having external rims, provided in the device.

16. The method of claim 15, wherein evacuating the gas through at least one gas evacuation passage is carried out by vacuum means.

17. The method of claim 16, wherein the vacuum means and the high-pressure gas supply are both regulated to induce substantially zero pressure forces on the object to be cleaned.

18. The method of claim 16, wherein the vacuum means evacuate substantially all the gas so that in effect a dynamically closed environment is formed substantially preventing mass flow of the gas with removed contaminants from escaping to ambient atmosphere.

19. The method of claim 1, further comprising providing a relative motion between the active surface of the device and the surface of the object to be cleaned.

20. The method of claim 19, wherein the relative motion is linear.

21. The method of claim 19, wherein the relative motion is angular.

22. The method of claim 20, wherein the relative motion is combined with linear motion.

23. The method of claim 19, wherein the relative motion is substantially parallel to the surface and the direction of the gas as it accelerates in the throat section.

24. The method of claim 1, wherein the active surface of the device is occasionally relocated from point to point to clean localized portions of the surface to be cleaned.

25. The method of claim 1, wherein the width of the throat section is controlled using physical support.

26. The method of claim 1, wherein the width of the throat section is controlled using non-contact support.

27. The method of claim 26, wherein the non-contact support comprises air-cushioning.

28. The method of claim 1, wherein the gas is air.

29. The method of claim 1, wherein the gas is helium.

30. The method of claim 1, wherein the gas is Nitrogen.

31. The method of claim 1, wherein the gas is heated.

32. The method of claim 1, wherein the surface to be cleaned is heated.

33. The method of claim 1, wherein the gas is excited in high-frequency a periodic fluctuations.

34. The method of claim 33, wherein the gas is excited by piezoelectrically.

35. The method of claim 33, wherein the gas is excited by acoustically.

36. A cleaning device for removing contaminants from a surface of an object to be cleaned, the device adapted to be fluidically connected to a high-pressure gas supply, the device comprising:

at least one high-pressure passage with a predetermined miniature lateral scale with a high-pressure outlet for accelerating the gas, the high-pressure outlet characterized by at least one narrow lip, the outlet and the narrow lip defining an active surface,

whereby when the active surface of the cleaning device is brought to a predetermined miniature gap from, and substantially parallel to, the surface, thus defining a throat section between said at least one narrow lip and the surface of the object to be cleaned, wherein the gap is the width of the throat section, and when the gas is accelerated to about sonic speeds at the throat section, lateral aeromechanic removal forces are produced that act on the contaminants.

37. The device of claim 36, wherein the width of the throat section is controlled by a mechanical means.

38. The device of claim 36, wherein the width of the throat section is controlled by an aeromechanical means.

39. The device of claim 36, wherein the width of the throat section is set to be in the order of 100 to 1000 microns.

40. The device of claim 36, wherein the width of the throat section is set to be about 30 to 100 microns.

41. The device of claim 36, wherein the width of the throat section is set to be about 30 microns or less.

42. The device of claim 36, wherein the narrow lip is sharp.

43. The device of claim 36, wherein the lateral scale of the high-pressure passage is about the same in size as the width of the throat section.

44. The device of claim 36, wherein the lateral scale of the high-pressure passage is significantly larger than the width of the throat section.

45. The device of claim 36, wherein the lateral scale of the high-pressure passage is significantly smaller than the width of the throat section.

46. The device of claim 36, wherein pressure of the high-pressure gas supply is regulated.

47. The device of claim 36, wherein pressure of the high-pressure gas supply is up to 5 bars.

48. The device of claim 36, wherein pressure of the high-pressure gas supply is up to 20 bars.

49. The device of claim 36, wherein pressure of the high-pressure gas supply is up to 100 bars.

50. The device of claim 36, further comprising at least one gas evacuation passage.

51. The device of claim 50, wherein said at least one gas evacuating passage is connected to a vacuum pump.

52. The device of claim 36, further comprising a relative motion means, for providing relative motion between the active surface of the device and the surface to be cleaned.

53. The device of claim 52, wherein the relative motion means provides linear motion.

54. The device of claim 52, wherein the relative motion means provides angular motion.

55. The device of claim 54, wherein the relative motion means facilitates motion combined with linear motion.

56. The device of claim 52, wherein the relative motion is provided by mechanical means.

57. The device of claim 52, wherein the relative motion is provided by aeromechanical means.

58. The device of claim 36, wherein the active surface of the device is adapted to be occasionally relocated from point to point to clean localized portions of the surface to be cleaned.

59. The device of claim 36, wherein the cleaning head unit is supported by mechanical means.

60. The device of claim 36, wherein the cleaning head unit is supported by an air-cushion.

61. The device of claim 36, wherein the object to be cleaned is held with contact by mechanical means.

62. The device of claim 36, wherein the object to be cleaned is supported by non-contact means.

63. The device of claim 62, wherein the non-contact means comprises an air-cushion.

64. The device of claim 36, wherein the cleaning head is integrated in a non-contact supporting platform.

65. The device of claim 36, wherein the high-pressure outlet is elongated.

66. The device of claim 65, wherein said at least one lip comprises at least two elongated lips, whereby two opposing throat sections are defined having substantially equal widths.

67. The device of claim 65, wherein said at least one lip comprises at least two elongated lips, whereby two opposing throat sections are defined having different widths.

68. The device of claim 65, wherein said at least one lip comprises at least two elongated lips, whereby two opposing throat sections are defined, and wherein the passage is substantially perpendicular to the surface of the object to be cleaned.

69. The device of claim 65, wherein said at least one lip comprises at least two elongated lips, whereby two opposing throat sections are defined, and wherein the passage is tilted with respect to the surface of the object to be cleaned.

70. The device of claim 36, wherein the high-pressure outlet is annular.

71. The device of claim 36, wherein the active surface is flat.

72. The device of claim 36, wherein the active surface is arcuate.

73. The device of claim 36, wherein the active surface corresponds in shape to the shape of the surface of the object to be cleaned.

74. The device of claim 36, wherein said at least one high-pressure passage includes a flow restrictor.

75. The device of claim 74, wherein the flow restrictor exhibits self-adaptive return spring properties.

76. The device of claim 75, wherein the flow restrictor is an electromechanical control valve.

77. The device of claim 74, further provided with at least one gas evacuation passage, which includes a flow restrictor.

78. The device of claim 36, comprising at least two high-pressure outlets, the outlets arranged in a substantially parallel orientation.

79. The device of claim 36, comprising at least two high-pressure outlets, the outlets arranged in a substantially orthogonal orientation.

80. The device of claim 36, wherein at least one high-pressure outlet is provided that is divided into sectors that can be operated separately.

81. The device of claim 36, comprising at least one high-pressure outlet that can be relocated to a new operational location between two consecutive cleaning sequences.

82. The device of claim 36, comprising at least one high-pressure outlet that is parallel to the object where the object is oriented without any respect to gravity.

83. A cleaning system for removing contaminants from a surface of an object to be cleaned, the system adapted to be fluidically connected to a high-pressure gas supply, the system comprising:

at least one cleaning head comprising at least one high-pressure passage with a predetermined miniature lateral scale with a high-pressure outlet for accelerating the

gas, the high-pressure outlet characterized by at least one narrow lip, the outlet and the narrow lip defining an active surface,

supporting means for supporting the object to be cleaned;

relative motion means for providing relative motion between the surface of the object to be cleaned and said at least one cleaning head,

whereby when the active surface of the cleaning device is brought to a predetermined miniature gap from, and substantially parallel to, the surface, thus defining a throat section between said at least one narrow lip and the surface of the object to be cleaned, wherein the gap is the width of the throat section, and when the gas is accelerated to about sonic speeds at the throat section, lateral aeromechanic removal forces are produced that act on the contaminants.

84. The system of claim 83, wherein the system is configured for round objects to be cleaned.

85. The system of claim 83, wherein the system is configured for rectangular objects to be cleaned.

86. The system of claim 83, wherein the supporting means comprises a platform that supports the object, at least partly, without contact by an air-cushion from at least one side.

87. The system of claim 86, wherein the air-cushion is vacuum-preloaded.

88. The system of claim 83, wherein the supporting means comprises a platform that supports the object, at least partly, with contact.

89. The system of claim 83, wherein mechanical means employing friction are used to provide relative motion, by conveying the object.

90. The system of claim 83, wherein mechanical means employing gripping of the object are used to convey the object in order to provide relative motion.

91. The system of claim 83, wherein at least one cleaning head is movable in order to provide the relative motion.

92. The system of claim 83, where said at least one cleaning head and the object to be cleaned are movable in order to provide the relative motion.

93. The system of claim 83, further comprising heating means.

94. The system of claim 93, wherein the heating means comprises a heater for heating the gas.

95. The system of claim 93, wherein the heating means comprises a heater for heating the surface of the object to be cleaned.

96. The system of claim 83, wherein wetting means are provided for wetting the surface to be cleaned, in order to reduce adhesive forces acting on the contaminants.

97. The system of claim 83, wherein an ionizer is provided for ionizing the gas.

98. The system of claim 83, wherein an actuator is provided for exciting the gas to high frequencies periodic fluctuations.

99. The system of claim 83, wherein an optical scanner is provided for inspecting the surface to be cleaned and monitoring removal of contaminants.